





# Pushbutton or logic controls nonvolatile DAC

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**F**OR MANUAL CONTROL of analog signals, it's hard to beat the venerable precision multitrans potentiometer's simplicity, resolution, and power-off nonvolatility. When digital control of an analog parameter is the design objective, a universe of DACs is available to the designer. The circuit in Figure 1, however, has manual-pushbutton and CMOS/TTL-compatible digital interfaces to a 10-bit, nonvolatile, two- or four-quadrant multiplying DAC. The heart of the circuit is the Xicor (Milpitas, CA) X9511 PushPot series of digitally controlled potentiometers. These devices implement a convenient up/down response to either ground-referenced contact closures (with built-in debounce and pullup provisions) or open-collector/drain digital pulses.

Other useful features of these digital potentiometers include a  $\pm 5V$  analog-signal range and automatic storage and retrieval of settings with power-on/off

cycles via an on-chip EEPROM. The potentiometer's only shortcoming in this context is its resolution is inadequate for precision applications (only 32 distinct settings, equivalent to a mere five bits). To overcome this limitation, the circuit combines two PushPots with a summing op-amp buffer to achieve nearly 10-bit resolution. IC<sub>1</sub> provides a weighted sum of the wiper voltages of P<sub>2</sub> (coarse input) and P<sub>1</sub> (fine input) in the ratio of 25.5-to-1. This operation provides a composite resolution of  $32 \cdot (25.5 + 1) = 848$  distinct settings, equivalent to 9.7 bits.

The missing 0.3 bits are lost to the good-but-still-only-finite differential linearity of the X9511 (Xicor specifies  $\pm 0.2$  LSBs) and the consequent need to give a less-than-ideal weight ( $32 \times 0.8$  instead of 32) to P<sub>2</sub> to guarantee overall DAC monotonicity. The resultant two-quadrant (R<sub>2</sub>=10 kV, R<sub>3</sub> omitted) gain equation

is  $V_{OUT}/V_{IN} = (25.5 \times P_2 + P_1 - 31)/761$ . Thus, two-quadrant gain runs from -0.04 to 1.04 in steps of 0.0013, as P<sub>1</sub> and P<sub>2</sub> settings vary from (0,0) to (31,31).

Optionally, you can obtain four-quadrant multiplication by adding one resistor to the circuit, with the value  $R_3 = R_2 = 20$  kV. Gain then becomes  $V_{OUT}/V_{IN} = (25.5 \times P_2 + P_1 - 410)/380$  and ranges from -1.08 to 1.08 in steps of 0.0026, as P<sub>1</sub> and P<sub>2</sub> vary from 0 to 31. The loading of P<sub>1</sub> by R<sub>1</sub> is light enough to produce a negligible effect on linearity. Connecting Pin 7 (automatic store enable) of P<sub>1</sub> and Pin 7 of P<sub>2</sub> to ground enables automatic storage of potentiometer settings to internal EEPROM upon power-down. The circuit then automatically retrieves the settings on power-up. (DI #2269).

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Use a pushbutton or provide a digital signal to choose a nonvolatile analog output with nearly 10-bit resolution.

